International Journal of Mining Science and Technology 27 (2017) 49–55

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Coal and gas outburst dynamic system

Fan Chaojun [a], Li Sheng [a,b,c,*], Luo Mingkun [a], Du Wenzhang [a], Yang Zhenhua [a]

[a] College of Mining Engineering, Liaoning Technical University, Fuxin 123000, China
[b] State Key Laboratory for GeoMechanics and Deep Underground Engineering, China University of Mining & Technology, Xuzhou 221116, China
[c] State Key Laboratory of Coal Resources and Safe Mining, China University of Mining & Technology, Xuzhou 221116, China

ARTICLE INFO

Article history:
Received 3 June 2016
Received in revised form 19 August 2016
Accepted 12 October 2016
Available online 7 December 2016

Keywords:
Coal and gas outburst
Dynamic system
Coal-gas medium
Geology dynamic environment
Mining disturbance
Stress-seepage-damage coupling model

ABSTRACT

Coal and gas outburst is an extremely complex dynamic disaster in coal mine production process which will damage casualties and equipment facilities, and disorder the ventilation system by suddenly ejecting a great amount of coal and gas into roadway or working face. This paper analyzed the interaction among the three essential elements of coal and gas outburst dynamic system. A stress-seepage-damage coupling model was established which can be used to simulate the evolution of the dynamical system, and then the size scale of coal and gas outburst dynamical system was investigated. Results show that the dynamical system is consisted of three essential elements, coal-gas medium (material basis), geology dynamic environment (internal motivation) and mining disturbance (external motivation). On the case of C13 coal seam in Panyi Mine, the dynamical system exists in the range of 8–12 m in front of advancing face. The size scale will be larger where there are large geologic structures. This research plays an important guiding role for developing measures of coal and gas outburst prediction and prevention.

1. Introduction

Coal and gas outburst is a complicated mine gas dynamic phenomenon, which seriously threats coal mine safety production [1]. Since the first-recorded coal and gas outburst happened in Isaac Coal Mine in Lule coal field in 1843, more than 40 thousand outbursts have occurred in the world. China ranks first place in the aspects of frequency and strength of outburst. In recent 20 years, China averagely increases 37 pairs of coal mine and more than 280 times outburst accident every year [2,3]. The coal and gas outburst occurred on October 20, 2004 in Daping Coal Mine, Zhengzhou Coal Group, and has caused serious gas explosion accident, which pushed 1894 tons of coal into the working face and caused 148 deaths [4]. In recent years, despite taking a lot of control measures, coal and gas outburst still occurred frequently with the increase of the depth and mining intensity.

Outburst mechanism is summed up in the following four aspects: the gas leading role hypothesis, the geostress leading role hypothesis, the chemical effect hypothesis, and combination hypothesis. And the last hypothesis has won the acceptance of most scholars, which considered that the outburst is the result of combined effect of stress, gas and coal [5].

Numerous experimental measurements and numerical simulations were conducted to investigate permeability and damage evolution process in coal seam. Sobczyk et al. carried out a laboratory research of the influence of sorption processes on gas stresses leading to coal and gas outbursts [6]. Wang et al. conducted laboratory experiments to investigate the rapid decompression and desorption induced energetic failure in coal using a shock tube apparatus [7,8]. Xu et al. developed a coupled gas flow and solid deformation numerical model and applied to simulate the coal and gas outbursts in underground collieries using RFPA2D-gasflow [9]. An and Xue analyzed major parameters and the effect of gas desorption on outburst initiation, and established a model of gas migration and mechanical processes during excavation [10,11].

Meanwhile, some scholars have taken measures to forecast and prevent coal and gas outburst. Zhang and Li developed a multifactor pattern recognition technique to certain the possibility of coal and gas outburst [12]. Li and Zhao designed a simplex positioning algorithm for microseism monitoring and established a mine microseism monitoring system to canalize mine microseism [13]. Aguado and Nicieza established site measurements using some critical parameters for risk assessment and analyzed the gas behavior of subvertical coal seams in deep mines in order to prevent gas outburst [14]. The protective seam mining and gas drainage technique applied to strong coal and gas outburst dangers coal mine [15].

* Corresponding author. Tel.: +86 13941811946.
E-mail address: lisheng76@139.com (L. Sheng).

http://dx.doi.org/10.1016/j.ijmst.2016.11.003
2095-2686/

However, coal and gas outburst is much complex, and there are so many influencing factors. Coal and gas outburst has different patterns in the condition of different areas, different coal seams, different structures and different mining disturbances [12]. It is still a great topic to build a convincing and perfect cognition of coal and gas outburst.

In this paper, we propose the concept of coal and gas outburst dynamic system, and analyze interaction relationship of coal-gas medium, geological environment and mining disturbance in the dynamic system. A stress-seepage-damage coupling model will be established. And the size scale of the dynamic system will be analyzed by numerical simulation using this coupling model.

2. Dynamic system of coal and gas outburst

Coal is a porous medium, which contains a lot of gas. Under certain conditions geological environment and mining disturbance, the coal-gas medium will lose its stability and finally generate coal and gas outburst. Dynamic system of the coal and gas outburst consists of coal-gas medium, geological environment and mining disturbance (Fig. 1).

2.1. Coal-gas medium

Coal-gas medium composed of coal, water, air and other materials is the material basis and the necessary condition of coal and gas outburst. Its physical factors include coal thickness, firmness coefficient, porosity, permeability, gas pressure, gas content, initial speed of gas diffusion, ground water, etc. [12].

The adsorbed gas in the coal seam takes more than 80% of the total, while the content of adsorbed gas mainly depends on the porosity of coal, gas pressure and temperature. The gas in coal seam contains a large amount of internal energy, which will dramatically expanse under high pressure gradient and could throw out the broken coal. Generally speaking, the higher the gas pressure, the greater the gas content, the lower initial gas emission, the higher possibility of coal and gas outburst will be.

According to the fragmentation degree, coal structure is divided into primary constructional coal, ruptured coal, mortar coal and mylonitic coal [16]. The ruptured coal does not induce coal and gas outburst, but mylonitic coal and mortor coal can do it easily. Tectonic coal has a large porosity and a poor permeability, which benefits the gas preservation and will lead to relatively high gas pressure. The firmness coefficient of tectonic coal is significantly lower than primary constructional coal, and can be destroyed and thrown out easily [17]. Usually, the larger porosity and thickness of coal seam, the higher outburst risk will be. On the contrary, the larger permeability and firmness coefficient of coal seam, the lower outburst risk will be.

Water in the coal seam will fill the fractures and inhibit the gas desorption, diffusion and seepage. Generally, greater water content generates lower outburst risk.

2.2. Geological dynamic environment

Geological dynamic environment refers to the various geological factors which affect the properties of coal, and is the interior motivate of the coal and gas outburst. Geological dynamic environment includes geological structures (faults, folds, magmatite intrusion, and coal seam thickness variation), tectonic movement, coal seam depth. Han et al. discovered that coal and gas outburst usually occurred near the geological structures, such as the soft layer, faults, folds, igneous intrusion, and coal seam thickness variation [18].

Geological structure has a reconstruct function on the structure and mechanical properties of coal-gas medium, namely the damage effect. The coal structure in complex geological structure area is damaged seriously, with low strength and ability to resist coal and gas outburst. At the same time, tectonic stress in complex geological structure can often concentrate, which will increase the elastic potential energy in coal. Meanwhile, geological structure may lead to gas accumulation and high gas pressure. And high gas pressure gradient will cause tensile fracture of coal and increase the outburst risk.

Coal and gas outburst is the result of the interaction of the original crustal stress field and mining stress field caused by human activities [19]. Tectonic movement is the mechanical movement of the deformation and displacement of the lithosphere in the earth. The tectonic stress caused by tectonic movement is the maximum principal stress in coal-series strata. Horizontal extrusion stress often exceeds the vertical extrusion stress caused by the gravity of the overlying strata [16]. The nappe structure, syncline structure and structural depressions tend to have higher horizontal tectonic stress which provides a dynamic foundation for coal and gas outburst. In the process of tectonic evolution, these structures will compact and close the fractures and pores in the coal (rock) bodies and limit gas migration and dissipation, which has the sealing function to the coal and gas system. Therefore, the coal body

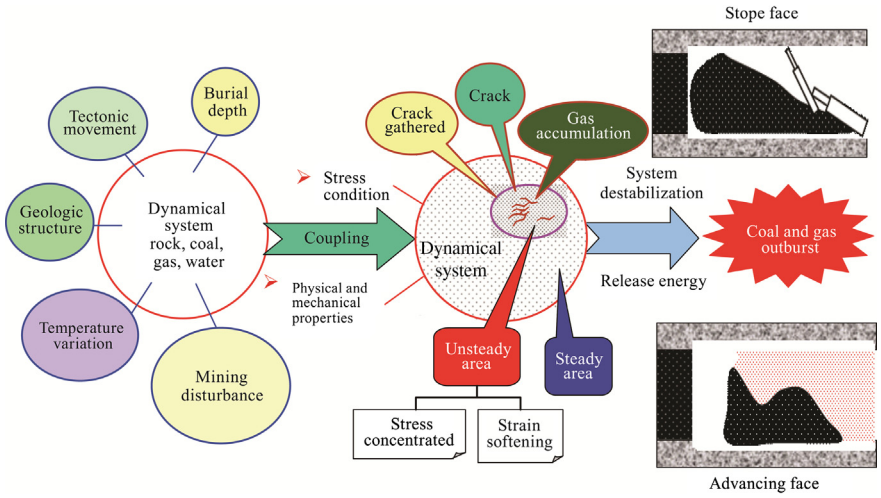

Fig. 1. Dynamic system of coal and gas outburst.